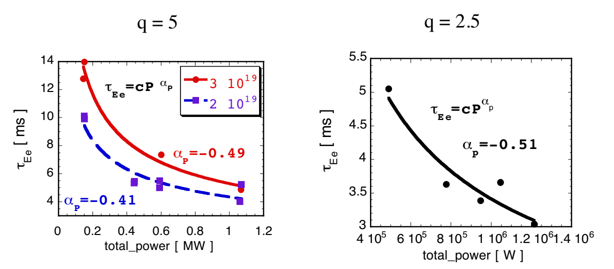
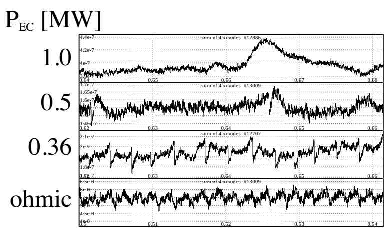
CONFINEMENT POWER DEGRADATION



Power scan
κ=1.31, Z=0.38m

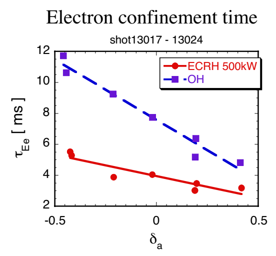
$-0.49 < \alpha_P < -0.41$ $\alpha_p = -0.51$

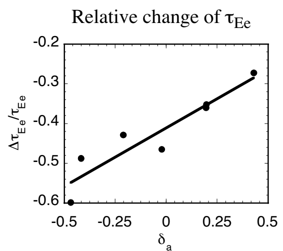
Electron confinement power degradation close to the usually expected α_P=-0.5, ($\tau_{Ee} \sim P^{-\alpha}P$)



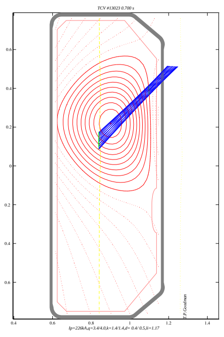
Sawteeth disappearing at high P_{EC}

CONFINEMENT and TRIANGULARITY δ





Triangularity δ-scan
0.5 MW, κ=1.33, q=3.5
$n_{eo}=2\times10^{19}m^{-3}$
Z=0.23m

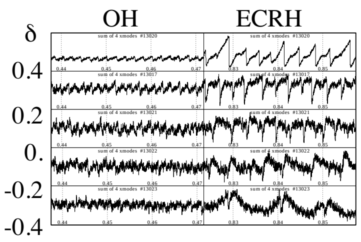


For optimal heating, deposition was placed close to q=1

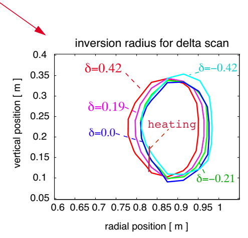
However, degradation appears stronger at negative δ in ECRH

Similar benefit of negative δ in ECRH as in OH at this power level

Heating outside q=1 at δ<0 is responsible for this effect at this power level



Sawteeth disappearing at negative δ



deposition inside q=1 for δ>0
deposition outside q=1 for δ<0

COUPLED POWER MEASUREMENTS

Power coupling to the plasma:
- from Diamagnetic Probe
- from Transport Calculations

AIM: Coupling efficiency k
k = absorbed power / wave power at tokamak port

COUPLED POWER from DIAMAGNETIC PROBE

Measured from the time derivative of the plasma stored energy.
Same shots as for the transport analysis

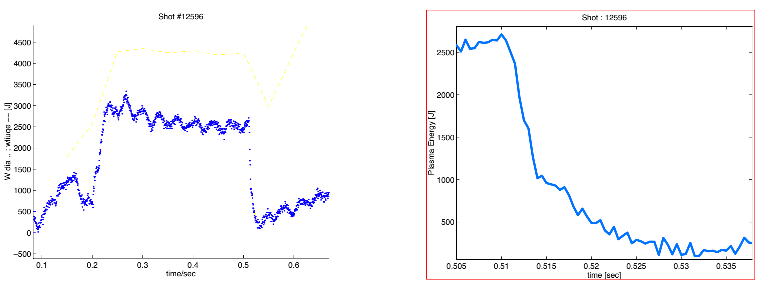


Table 1:

early shots	P_{ECRH}[kW]	k_{DML}	k_{ASTRA}
ρ=0.6 11116	500	11±3 %	65 %
ρ=0.3 11118	500	63±11 %	65 %
ρ=0. 11119	500	60±20 %	65 %
recent shots	P_{ECRH}	k_{DML}	k_{ASTRA}
"3 keV" 12443	465	75±5 %	100 %
"4 keV" 12596	920	70±15 %	-

Comparison of the two Methods (Diamagnetism and Transport):

- power coupling efficiency from diamagnetism similar to the one from transport, possibly smaller (but taking into account the variable P_{OH} adds about 10%)
- when diamagnetism shows good coupling, so do transport calculations

COUPLED POWER from ASTRA TRANSPORT CODE

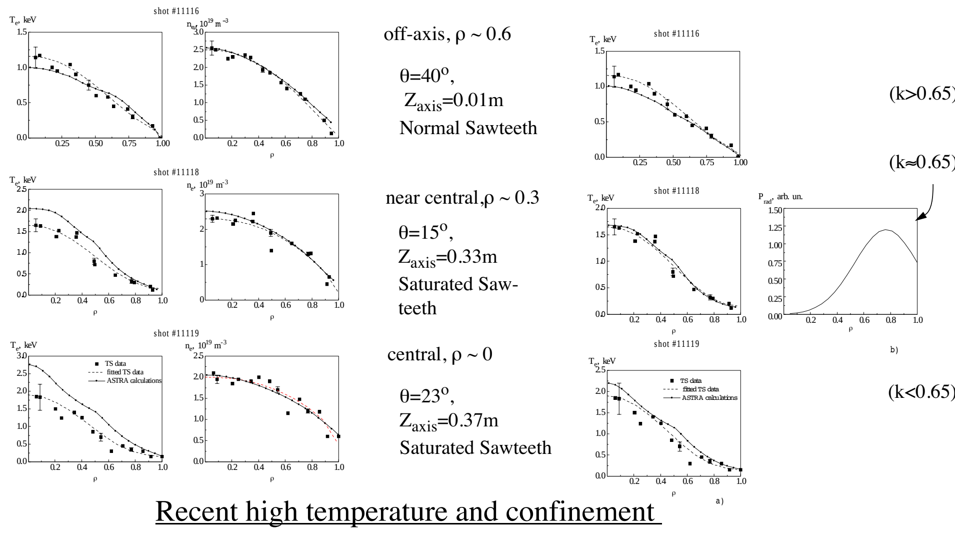
The present aim of these transport simulations (ASTRA) is to evaluate the fraction of power deposited in the plasma:

1. The T-10 canonical transport model in ASTRA code was used without any change, reproducing correctly TCV Ohmic data: central T_{e0}, and profiles T_e(r,t), within ± 10%.
   The T-10 transport model fits therefore correctly TCV Ohmic data.
2. ECRH heated plasmas were then simulated, static and Z-sweeps (static cases shown)
3. The simulations require P_{ab} = 0.65 P_{in} to match experimental temperature profiles for the early q=3 shots (#11116-19) with oblique launch.
4. Recent high performance q=6 shots with quasi-horizontal launchsuggest a power absorption close to unity ($P_{ab} \sim P_{in}$) if the same confinement model continues to be used.

Early Simulations

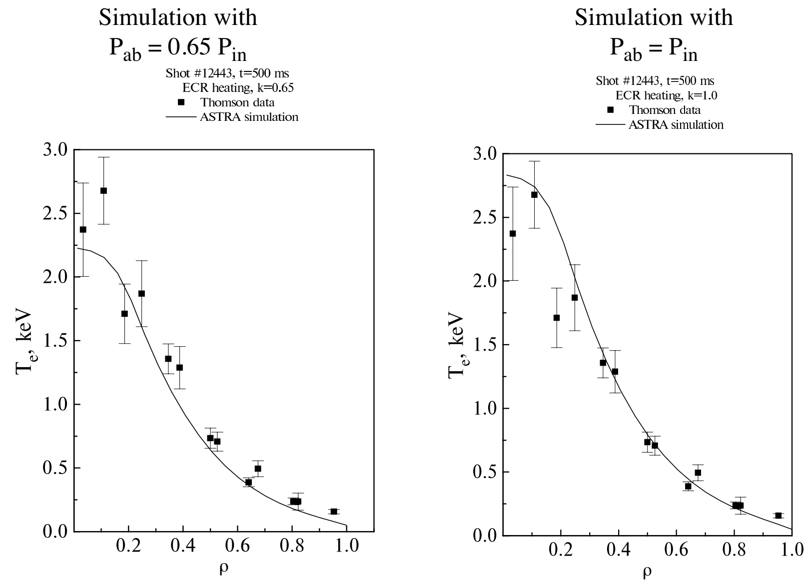
q=3.15, κ=1.26, B_T=1.45T, P_{EC} = 0.5 MW, 2 ≤ n_{e0} ≤ 2.5 $10^{19}m^{-3}$
Normal or Saturated Sawteeth

Simulations using P_{ab} = P_{in} Simulations using P_{ab} = 0.65 P_{in}



Recent high temperature and confinement

Confinement series typical shot
q=6, κ=1.31, B_T=1.44T, n_{e0}=2.0 $10^{19}m^{-3}$, P_{EC} = 0.5 MW
No sawteeth



Recent data show that $P_{ab} \sim 1\ P_{in}$ (when keeping the same transport model)

CONCLUSIONS

ELECTRON CYCLOTRON WAVE SYSTEM

- The first MW (out of 4.5) is operational, with pulses of 1 MW, 1s.
- Mirrors are movable during a shot.
- Heating localization effects and confinement have been studied through launcher mirror sweep, vertical plasma sweep and B-field sweeps.

CONFINEMENT

- Electron temperature, and confinement time, depend on the localization of power deposition relative to the q=1 surface.
- Central electron temperature maximizes for a deposition on q=1.
- Confinement time is maximum and flat inside for heating inside q=1 surface.
- Confinement improves with q and n_e: Neo-Alcator-like.
- Confinement improves with negative triangularity: trend as in ohmic.
- The power degradation exponent is close to usally expected: $\alpha_P \sim -0.5$, ($\tau_{Ee} \sim P^{\alpha P}$), possibly helped by the effect of slight off-axis heating on profiles and MHD.
- MHD relaxations reduced at high P_{EC}, as for high q or negative δ

POWER COUPLING EFFICIENCY

- Diamagnetic probe and transport calculations show comparable coupling efficiency

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